INDOOR AIR QUALITY ASSESSMENT

Grace Baptist Christian Academy
1000 Oak Hill Avenue
Attleboro, MA 02703

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of James Mooney, Health Agent, Attleboro Health Department, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), Bureau of Environmental Health Assessment (BEHA) conducted an evaluation of the indoor air quality at the Grace Baptist Christian Academy (the Academy), located at 1000 Oak Hill Avenue, Attleboro, Massachusetts. On March 30, 2004, a visit to conduct an assessment was made to this building by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by Joe Adams, Facilities Manager, Jeffery Bailey, Senior Pastor and Mr. Mooney during the assessment. The assessment was prompted by mold growth experienced because of water damage sustained by building materials in the basement.

The Academy is a wood-framed building constructed in 1904 as a casino/resort. A two-story brick addition was built in the 1940s. Over the decades, the building has had a variety of uses, including a state hospital and nursing home. According to school officials, the building was reportedly vacant for approximately two years prior to occupancy by the Academy in June 2003.

In September 2003, Academy officials contracted with OccuHealth, Inc. (OccuHealth), an environmental consultant, to conduct mold testing. The OccuHealth report recommended remediation actions, which include: 1) sealing the basement and placing it under negative pressure; 2) repairing the porch above the laundry to prevent water penetration; 3) drying water-damaged building materials with commercial dryers; 4) removing all mold-colonized building materials; 5) HEPA-vacuuming, sanding or soda blasting then sanitize with a biocide any mold-colonized structural materials (e.g., joists, studs, foundation walls) that cannot be replaced; 6) operating dehumidifiers continuously during summer months to maintain relative humidity levels below 60% and 7) retesting air in the building upon completion of remediation activities (OccuHealth, 2003). The report also referenced the New York City Department of Health "Guidelines on Assessment and Remediation of Fungi in Indoor Environments". Following the OccuHealth assessment and per Board of Health officials, Academy officials began remediation activities (e.g., isolating the basement area) prior to the 2003-2004 school year. To prevent exposure, remediation activities were halted at the start of the school year. At the time of the assessment, no remediation activities were being conducted, and access to the basement was restricted. Academy officials reported that remediation would resume once summer break commenced in June, 2004.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). BEHA staff conducted a visual inspection for standing water, water-damaged building materials and microbial growth. Moisture content of water-damaged gypsum wallboard (GW), wooden trim and baseboard were measured with Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

Results

The Academy has a student population of approximately 85 in grades pre-school through 12 and a staff of 14. The tests were taken during normal operations. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in seven of eleven occupied areas surveyed, indicating inadequate air exchange most areas. It is important to note that all areas with carbon dioxide measurements below 800 ppm were empty or sparsely populated, which can greatly reduce carbon dioxide levels. The Academy does not have any means of mechanical ventilation, but uses windows to introduce fresh air. Without sufficient mechanical supply and exhaust ventilation, environmental pollutants can build up, which can lead to indoor air quality complaints.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times a room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature measurements ranged from 68° F to 72° F in occupied areas, which were close to the BEHA recommended comfort range. The temperature measurement for the basement laundry room was 63 ° F, below the recommended comfort range. However, the room is unoccupied. Moreover, access to this area is restricted. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78°

F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building lacking mechanical ventilation system.

The relative humidity measurements in the building ranged from 30 to 40 percent, which were below the BEHA recommended comfort range in the majority of areas. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As previously stated, water-damaged building materials were mold-colonized as a result of water infiltration, mainly through breaches in the porch above the laundry room. At the time of the assessment, the porch was covered with a tarpaulin to prevent additional damage until repairs resumed (Picture 1). Visible mold growth on a number of porous and non-porous surfaces was observed by BEHA staff. These included ceiling and wall plaster, wooden slats and metal pipes (Pictures 2-4). Breaches (e.g., utility holes) were noted in the basement ceiling (Picture 5) that can serve as pathways for movement of odors and particulates between the basement and first floor. Mold and related particulates can be irritating to sensitive individuals. To prevent mold-related odors from migrating to occupied areas of the building, the basement was sealed and depressurized through the operation of a commercial grade fan (Picture 6).

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned for removal of mold growth. The application of a mildewcide to moldy porous materials is not recommended.

BEHA staff examined the outside perimeter of the building to identify conditions that could provide a source for water penetration. In addition to breaches in the porch (Picture 1), a number of additional moisture penetration sources were identified:

- Damaged/dislodged gutters and downspouts around the perimeter of the building (Picture 7);
- Heavy moss growth along the perimeter of the building, indicating an area of chronic water accumulation (Picture 8);
- Clinging plants growth on exterior walls in several areas (Picture 9). Clinging plants can cause water damage to brickwork, as tendrils are inserted into brick and mortar. Water can penetrate into the brick along the tendrils and subsequently freeze and thaw during the winter. This freezing/thawing action can weaken brick and mortar, resulting in damage to this wall; and
- Open utility holes (Picture 10), which can provide entry for rodents and other pests.

The aforementioned conditions can undermine the integrity of the building envelope and provide a means of water entry by capillary action into the building through exterior walls, foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter. As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable (ND). Carbon monoxide levels measured inside the school were also ND (Table 1).

As mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standards requires outdoor air particle levels be maintained below 65 μg/m^3 over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 20 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 16 to 86 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors. The highest PM2.5 measurement was taken in classroom 6B. Airborne levels of fine particulate were most likely elevated due to sweeping of the classroom floor by occupants (Picture 11).

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. The faculty workroom contains two photocopiers. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). The copy room is not equipped with local exhaust ventilation to help reduce excess heat and odors.

Finally, in an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and lead to off gassing of VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Conclusions/Recommendations

The conditions present within the Grace Baptist Christian Academy require 3 types of remediation: A) prevention of water intrusion B) replacement/cleaning of materials stored in the basement and C) improvements to general indoor air quality. The recommendations made in the OccuHealth report dated September 18, 2003 should be implemented. The following recommendations are made as a compliment to the OccuHealth recommendations (OccuHealth, 2003).

A. Building Envelope/Water Intrusion

1. Continue with plans to make repairs to porch to prevent further water penetration.
2. Repair gutters and downspouts to direct rainwater away from the building.
3. Repair breaches in the building envelope (e.g., utility holes).
4. Remove clinging plants from exterior walls of building.

B. Mold Colonized Materials in the Basement

1. Remove mold contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (US EPA, 2001). The document is available at the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
2. Identify and seal any utility holes, chase ways or other openings between the basement and first floor (Picture 5).

C. General Air Quality

1. Use windows to introduce fresh air into classrooms. Open windows on both sides of the building to provide cross ventilation.
2. Examine the feasibility of providing mechanical supply and exhaust ventilation.
3. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
4. Consider installing local exhaust vents in teacher's workrooms to help reduce excess heat and odors from office equipment.
5. Consider adopting, the US EPA (2000b) document, Tools for Schools, in order to maintain a good indoor air quality environment at your building. The document is available at http://www.epa.gov/iaq/schools/index.html.
6. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhoFtme.htm.

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Picture 1

Porch Area Covered With Tarpaulins

Picture 2

Visible Mold Growth on Wall Plaster

Picture 3

Visible Mold Growth on Plaster Ceiling

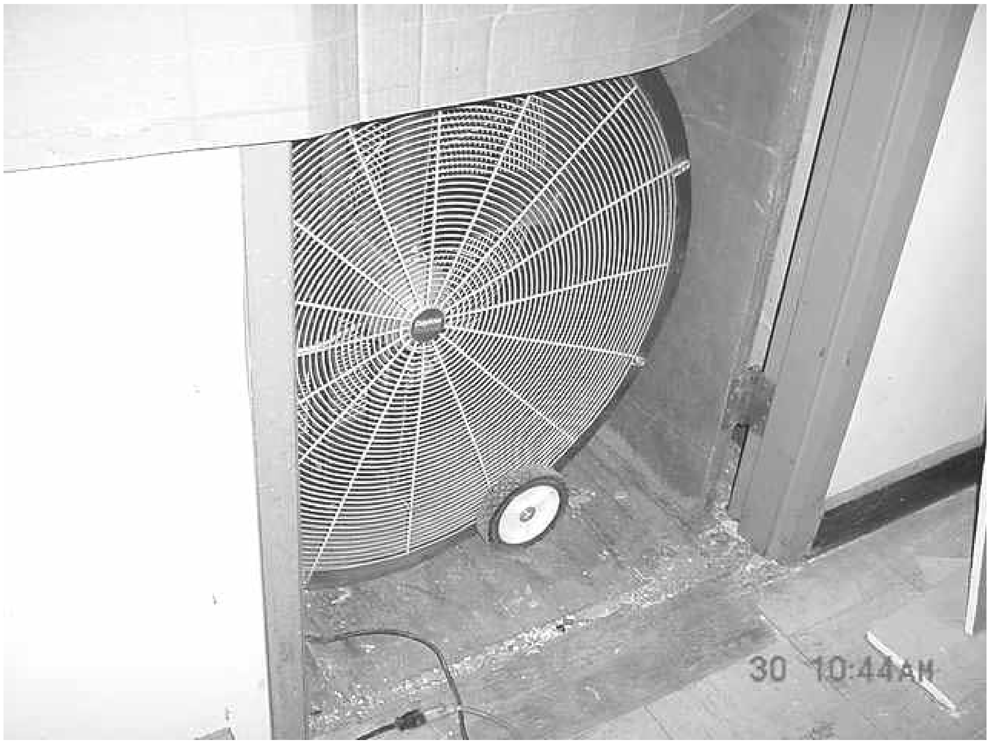
Picture 4

Visible Mold Growth on Iron Pipes

Picture 5

Open Utility Holes in Basement Ceiling, Note Mold Growth at Bottom of Photo, Indicated by Black Staining

Picture 6

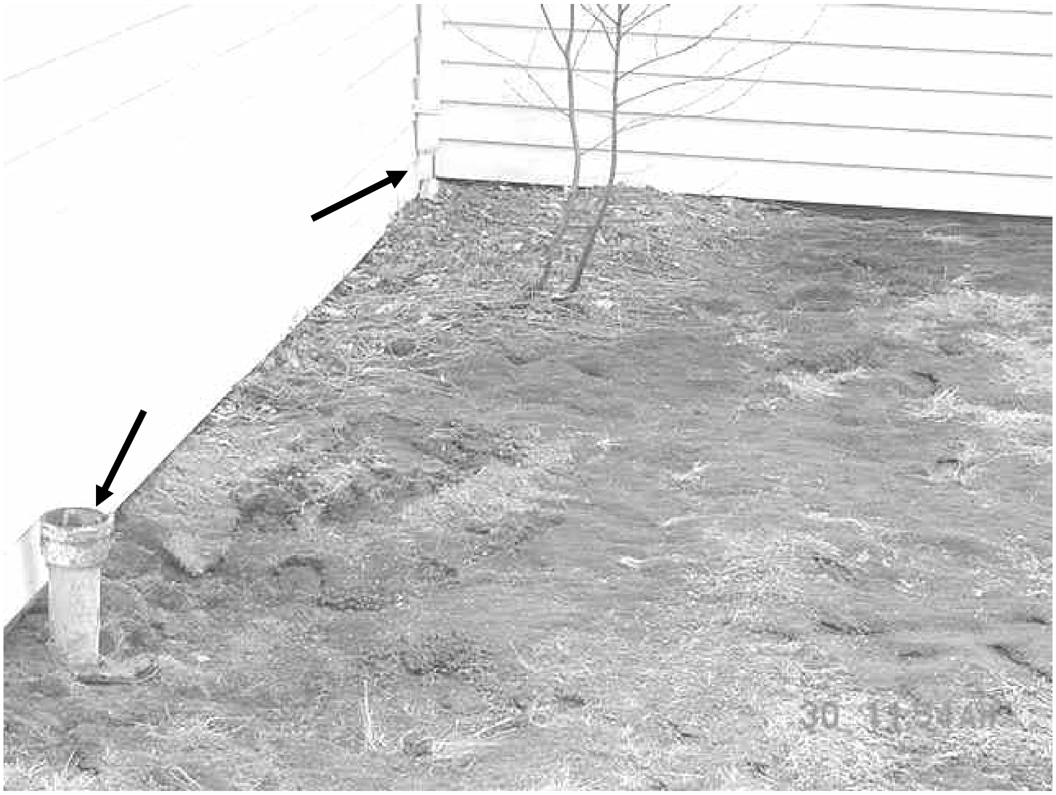


Commercial Grade Fan in Basement

Picture 7

Downspout Missing Elbow Extension Emptying Water Against Foundation

Picture 8



Heavy Moss Growth in Interior Corner of Building, Note Missing Downspout and Elbow Extension

Picture 9

Crawling Plants on Side of Building

Picture 10

Open Utility Hole

Picture 11

Evidence of Sweeping causing Elevated Airborne Particulates in Classroom 6B

Grace Baptist Christian Academy **Indoor Air Results**

Attleboro, MA **March 29, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background Outdoors	60	23	386	ND	ND	20					East winds, 5-10 mph; cloudy & cool
Laundry Room	63	35	405	ND	ND	19	4	Y			Visible mold on ceiling, wall plaster; unoccupied, Under negative pressure
Dining Hall	68	40	601	ND	ND	23	0	Y			Hallway door open; carpet to be removed over summer
A-5	71	39	1037	ND	ND	19	10	Y			Hallway door open
A-6	70	37	1184	ND	ND	15	9	Y			Hallway door open
A-10	71	37	1224	ND	ND	20	8	Y			Hallway door open
K-5	72	35	876	ND	ND	17	6	Y			Hallway door open; exterior door leaks/draft

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Grace Baptist Christian Academy

Attleboro, MA

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									Supply	Exhaust	
Library	70	30	737	ND	ND	19	0	Y			Hallway door open
11-B	72	36	1277	ND	ND	20	7	Y			
8-B	71	36	1656	ND	ND	38	11	Y			Hallway door open
6-B	71	35	1054	ND	ND	86	5				Hallway door open; utility holes around radiator pipes
12-B	71	31	653	ND	ND	17	0	Y			
Copy Room	71	32	651	ND	ND	16	1	Y			Photocopiers, no local exhaust

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